Response to the Peer Review Comments on the Draft Basin Plan Amendment for Nutrients in the Clear Lake Watershed from Dr. Wayne Carmichael, Department of Biological Sciences, CyanoHAB Services, Wright State University

Dr. Carmichael's comments are in plain text.
Regional Board responses are in **bold type**.

Comment 1: I have no experience with the two water quality models that Tetra Tech used for the Basin Plan. Therefore I have no comments in the area of model appropriateness, however the following concerns chlorophyll a.

The choice of chlorophyll-a to represent levels of algal growth is the acceptable method. Prokaryotic Cyanobacteria (blue-green algae) produce Chl-a (but not Chl B) and one of their characteristic pigment groups the phycocyanins can be used to distinguish them from other algal groups. Since cyanobacteria represent the primary algal type present phycocyanins would also have been an acceptable measure of the dominant algal biomass. Depending on how the basin plan is implemented it would be appropriate to use the new technology available for monitoring phycocyanins. Both Hydro Lab and Yellow Springs Instruments Inc. have developed an *in situ* sond probe system using fluorescence technology for continuous monitoring of cyanobacteria phycocyanin.

Staff agrees that it would be worthwhile to investigate measuring phycocyanins to determine algae biomass. However, the use of this new technology would be funding dependent. Algal productivity data used in the TMDL report was obtained by the California Department of Water Resources (DWR) in the form of algal counts per milliliter (#/mL). The data were obtained via grab samples, which were later analyzed under 200 magnification using a Sedgwick Rafter cell, or a type of slide for microscopic analysis. Phytoplankton were subsequently enumerated to genus and ultimately entered into an electronic database. This algae monitoring is funded by the state and will continue.

Comment 2: Nutrient and hydrologic conditions strongly influence planktonic and benthic cyanobacterial bloom dynamics in aquatic ecosystems ranging from streams and lakes to coastal ecosystems. Urbanization, agricultural and industrial development have led to increased nitrogen (N) and phosphorus (P) discharge, which affect cyanobacterial bloom dynamics and their impact on receiving waters. The amounts, proportions and chemical composition of N and P sources can influence the composition, magnitude and duration of blooms. Freshwater systems having low molar ratios of both total and soluble (biologically-available) N to P (<15) are most likely to experience cyanobacterial dominance (Smith 1983, 1990). Conversely, waters having molar N:P ratios in excess of 20 are more likely to be dominated by eukaryotic algal taxa (Smith 1983). (quoted from Paerl 2005)

Smith VH (1983) Low nitrogen to phosphorus ratios favor dominance by blue-green algae in lake phytoplankton. Science 221:669-671

Smith VH (1990) Nitrogen, phosphorus, and nitrogen fixation in lacustrine and estuarine ecosystems. Limnol Oceanogr 35:1852-1859.

Paerl, H. W. Nutrient and other environmental controls of harmful cyanobacterial blooms along the freshwater-marine continuum. In Proceedings of International Symposium on Cyanobacterial Harmful Algal Blooms (ISOC-HAB), September 6-10, 2005, Research Triangle Park, NC, USEPA.

The N:P ratios recorded for Clear Lake (between 7 and 15, Table 3-1) are in agreement with the published literature. This reviewer is in agreement that internal and external loading of phosphorus is a key component of the algae bloom (in particular cyanobacteria blooms) problem in Clear Lake. Reduction of external loading to the compliance levels reported will reduce total P inputs and allow, over time, a reduction in available total P. Internal P loading will also be reduced (over a longer period of time). The target date of 2011 should allow sufficient time for internal loads to be reduced but it is not clear that internal loading will be reduced. One recommendation would be to study the conditions for internal loading (in addition to dissolved oxygen and temperature) and try and determine if time would influence a change in P release from the sediments.

Response:
The study suggested by the reviewer on the internal loading of phosphorus is an example of continuing work that is proposed under the TMDL implementation plan.

Comment 3: Since P is a key limiting nutrient in algal growth and the N:P ratios in Clear Lake favor Cyanobacteria growth, and since Cyanobacteria contain Chl a, linking Chl-a and P is appropriate. Prokaryotic Cyanobacteria also produce the more characteristic pigment for their group – Phycocyanin. This pigment can be used to distinguish them from other algal groups. Since cyanobacteria represent the primary algal type present phycocyanin would also have been an acceptable measure of the dominant algal biomass. Depending on how the basin plan is implemented it would be appropriate to use the new technology available for monitoring phycocyanin. Both Hydro Lab and Yellow Springs Instruments Inc. have developed an *in situ* sond probe system using fluorescence technology for continuous monitoring of cyanobacteria phycocyanin.

Response:
Agree. See response to #1, above.

Comment 4: Water clarity can be influenced by factors such as suspended materials (sediments etc), but in Clear Lake clarity is influenced mainly by algal biomass. In the summer the algae that dominate are the planktonic Cyanobacteria *Anabaena, Aphanizomenon* and *Microcystis*. During summer, when runoff subsides, externally-supplied P loads (from point sources) or internally-generated P loads released from hypoxic sediments tend to contribute more to nutrient loading. P enrichment (declining N:P ratios) can select for N2 fixing species-also called diazotrophic species. In Clear Lake these are represented mainly by *Anabaena and Aphanizomenon*. Nondiazotrophic species, represented in Clear Lake mainly by Microcystis, can remain a significant fraction of the phytoplankton as they are able to utilize fixed N produced and released by N2 fixers. Using water clarity measurements via a secchi disc is an acceptable indicator of nutrient conditions if it used in conjunction with phytoplankton and nutrient monitoring.

Response:

Comment noted. Secchi depth monitoring in Clear Lake is conducted in conjunction with phytoplankton and nutrient monitoring.

<u>Comment 5:</u> on the Amendment To The Water Quality Control Plan for the Sacramento River and San Joaquin River Basins For The Control of Nutrients in Clear Lake - Peer Review Draft Staff Report

This reviewer agrees with the staff report summary. If the comments in the rest of this review are considered the Basin Plan for Clear Lake will have a good chance of reversing the eutrophication status of Clear Lake and its cyanobacteria harmful algae blooms.

Response:
Comment noted.

<u>Comment 6:</u> Yes the scientific portion of the proposed rule is based upon sound science.

Response:
Comment noted.

<u>Comment 7:</u> The dominant cyanobacteria phytoplankton in Clear Lake, *Anabaena, Aphanizomenon and Microcystis* (the notorious trio, “Annie, Fannie and Mike”) can form metalimnetic blooms in nutrient enriched (N and P) lakes and reservoirs. Odor and taste producing episodes co-occur under these circumstances. In clearer waters where light reaches the bottom, benthic N_2 fixing and non-fixing assemblages (e.g. Lyngbya, Oscillatoria, Microcoleus, Scytonema, Phormidium) can predominate. Mixed assemblages often persist as a bloom “consortium” during summer and fall, until unfavorable physical conditions such as cooling (<15 ^{o}C) and water column turnover take place. The three genera *Anabaena, Aphanizomen and Microcystis* are also the three main cyanobacteria producers of potent toxins called cyanotoxins (Carmichael, 1997, 2001; Carpenter and Carmichael 1995).

Cyanobacteria toxins (cyanotoxins) include cytotoxins and biotoxins with biotoxins being responsible for acute lethal, acute, chronic and sub-chronic poisonings of wild/domestic animals and humans. The biotoxins include the neurotoxins; anatoxin-a, anatoxin-a(s) and saxitoxins plus the hepatotoxins; microcystins, nodularins and cylindrospermopsin (Carmichael et al. 2001, Chorus and Bartram 1999).

If blooms of these toxigenic cyanobacteria continue to occur they should be monitored for cyanotoxins and appropriate management and mitigation programs be put in place. The current basin plan for Clear Lake will certainly help in moderating and reducing these potentially lethal bloom forming cyanobacteria.

Carmichael, W.W. 1997. The Cyanotoxins. in Advances in Botanical Research (ed Callow, J.) 27, 211-256 Academic Press, London.

Carmichael, W.W. 2001. Health Effects of Toxin Producing Cyanobacteria: "The CyanoHABS". Human and Ecological Risk Assessment. 7(5): 1393-1407.

Carmichael, W.W., Azevedo, M.F.O., An, J.S., Molica, R.J.R., Jochimsen, E.M., Lau, S., Rinehart, K.L., Shaw, G.R., Eagelsham, G.K. 2001. Human Fatalities from Cyanobacteria: Chemical and Biological Evidence for Cyanotoxins. Environmental Health Perspectives. 109 (7):663-668.

Carpenter, E.J., Carmichael, W.W. 1995. Taxonomy of Cyanobacteria. in Hallegraeff, G.M. et al. (eds.) Manual on Harmful Marine Microalgae p. 373-80. IOC Manuals and Guides No. 33 UNESCO.

Chorus, I., Bartram, J. (eds.) 1999. Toxic Cyanobacteria in Water: A Guide to Their Public Health Consequences, Monitoring and Management. World health Organization, E&FN Spon, Routledge, London.

Response:
There is an existing statewide initiative to address blue-green algae toxins. The State Water Resources Control Board will have a policy completed in June 2006. More information can be found on the State Water Board's website at: http://www.waterboards.ca.gov/bluegreenalgae/index.html. Regional Board staff will work with the County of Lake to study this issue in Clear Lake.

Note: On page 13 and 21 of the Tetra Tech CL Draft—*Aphanizomenon* is spelled incorrectly.

Response:
Comment noted.